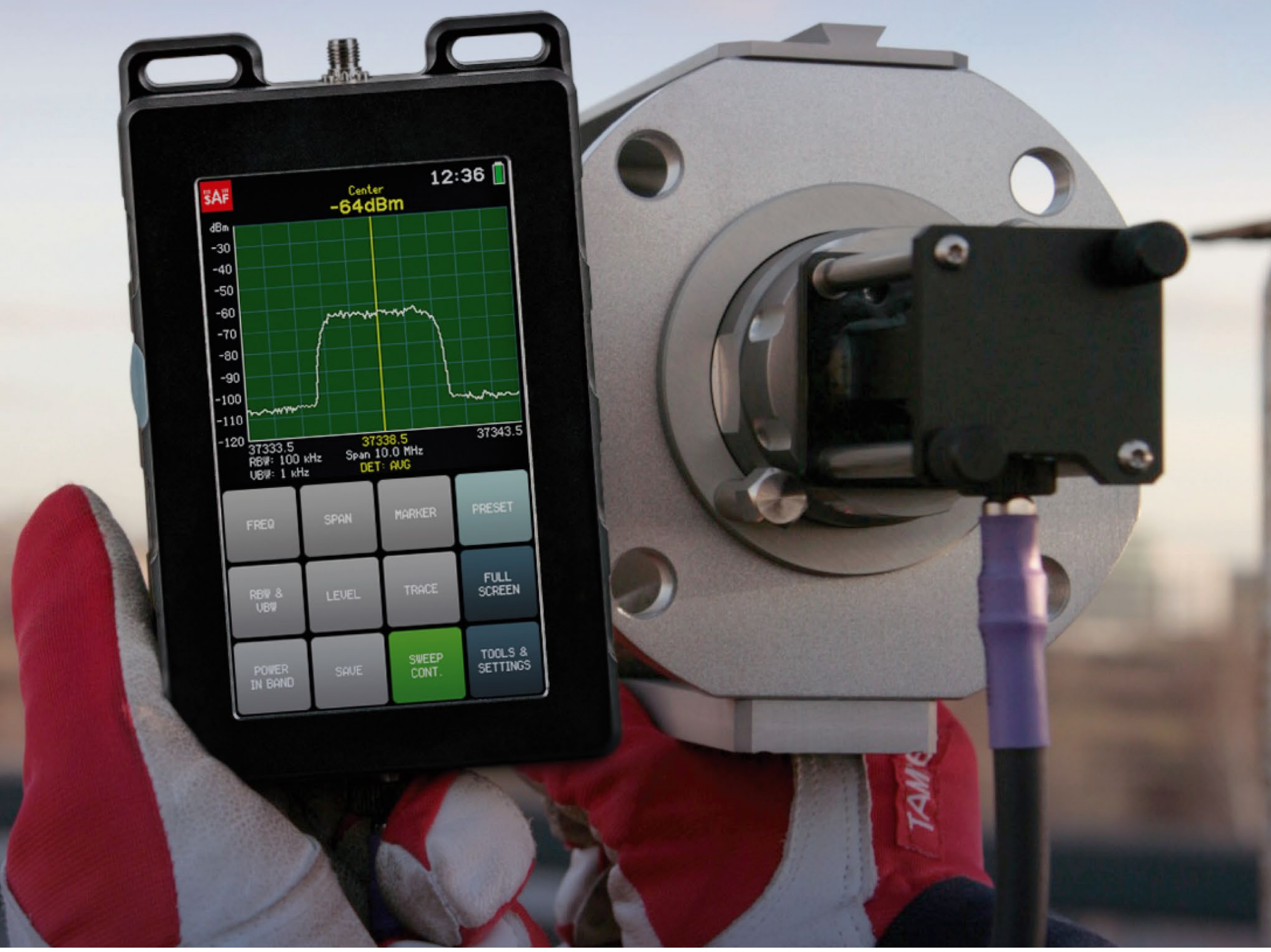
# Improve Antenna Alignment

## with Handheld Spectrum Analyzers




APPLICATION NOTE

Sometimes the most obvious aspect of radio link deployment is overlooked. It's also the one that has the greatest potential for improvement. **Antenna alignment** is the part of link deployment that cannot be ignored or performance will suffer. Despite its importance, many people in the industry lack knowledge about the specifics of aligning radios properly.

Misalignment consequences can be damaging – economically and in degraded performance. Unstable operation of the link will require engineers to return to the site repeatedly until the problem is resolved. Successful antenna alignment usually is straight-forward but often it can become complicated. RF practitioners know the moment they realize that the tools in their toolbox are not enough to solve the problem. A frustrating and time-consuming process is ahead of them in these scenarios.

Even when theory of radio signal propagation and reception is well understood, there needs to be knowledge of existing practical solutions options. These include:

- Precision
- Speed
- Cost Efficiency

Economics occasionally is overlooked when examining effective and quick link deployment. Equipment cost, however, is the factor that decides if each team member can be equipped with the tools that will save time and allow the project to be delivered on schedule.

In this application note, a solution that combines all three points is proposed using a handheld spectrum analyzer, such as the **Spectrum Compact** *(Fig. 1)*. It demonstrates a signal in a way that is not accessible by multimeters. The spectrum analyzer displays the signal shape in the frequency domain, compared to a multimeter that only provides value equal to the integral over the frequency span.


Fig. 1. Spectrum Compact handheld spectrum analyzer.

# Antenna Alignment Theoretical Groundwork

Ensuring proper antenna alignment begins well before a field technician climbs the tower. Preparation starts with establishing stated goals. It is highly recommended to use planning tools to avoid manual calculations. SAF Tehnika has developed a **path calculator application**. Users simply input known information on the design of the link into the application, such as:

- Transmitter and receiver coordinates.
- Height of the antenna; ground elevation is calculated automatically based on coordinates.
- Frequency of transmitted signal.
- Antenna diameters.
- Transmitter power and operational mode.

When all parameters are input, the **received signal level (dBm)** is calculated. The result is the threshold to achieve when aligning the antennas. Extra losses that may occur along the signal path can be added in the path calculator. Usually, the target value of the signal level during the antenna alignment will be within +/- 3dB of the calculated value.

# Testing the Transmitter

While both parts of the link are not mounted, crews should check whether transmitter parameters are behaving as intended. The SAF Tehnika Spectrum Compact handheld spectrum analyzer can perform these measurements seamlessly *(Fig. 2)*. It is designed for field use, but its functionality is more than enough to effectively test equipment prior to deployment.

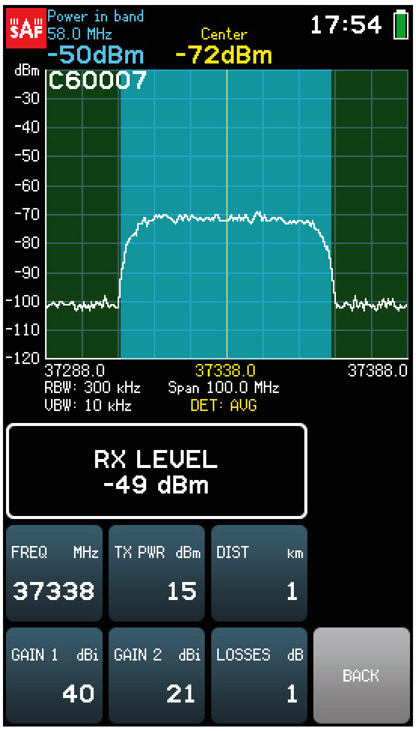



Fig. 2. Typical signal measurement.

Before connecting the Spectrum Compact to the transmitter *(Fig. 3)*, make sure to use an external attenuator. Measuring a transmitter's signal without proper attenuation might damage the analyzer's hardware, as it is intended for use with the signal in the distance.

Once attenuation is set up correctly, troubleshooting can be performed. Set the expected center frequency and frequency span. If the radio works correctly, the signal will appear on the analyzer's display.

Once the signal is located, check whether the:

- Form of the signal is in accordance with stated expectations. Is it symmetrical? Are there any unexpected spikes or notches?
- Signal level is in line with transmitter's power (account for the difference due to attenuation).
- Bandwidth of the signal corresponds to the expected value.

If any parameter is not within the transmitter specification, it needs to be examined further. It may indicate antenna mechanical issues – both the feeder and the adapter should be checked.

Using a spectrum analyzer allows field technicians to acquire all this information in seconds. It is important to save the measurement data, so it can be used as a baseline comparison when aligning antennas in the field.

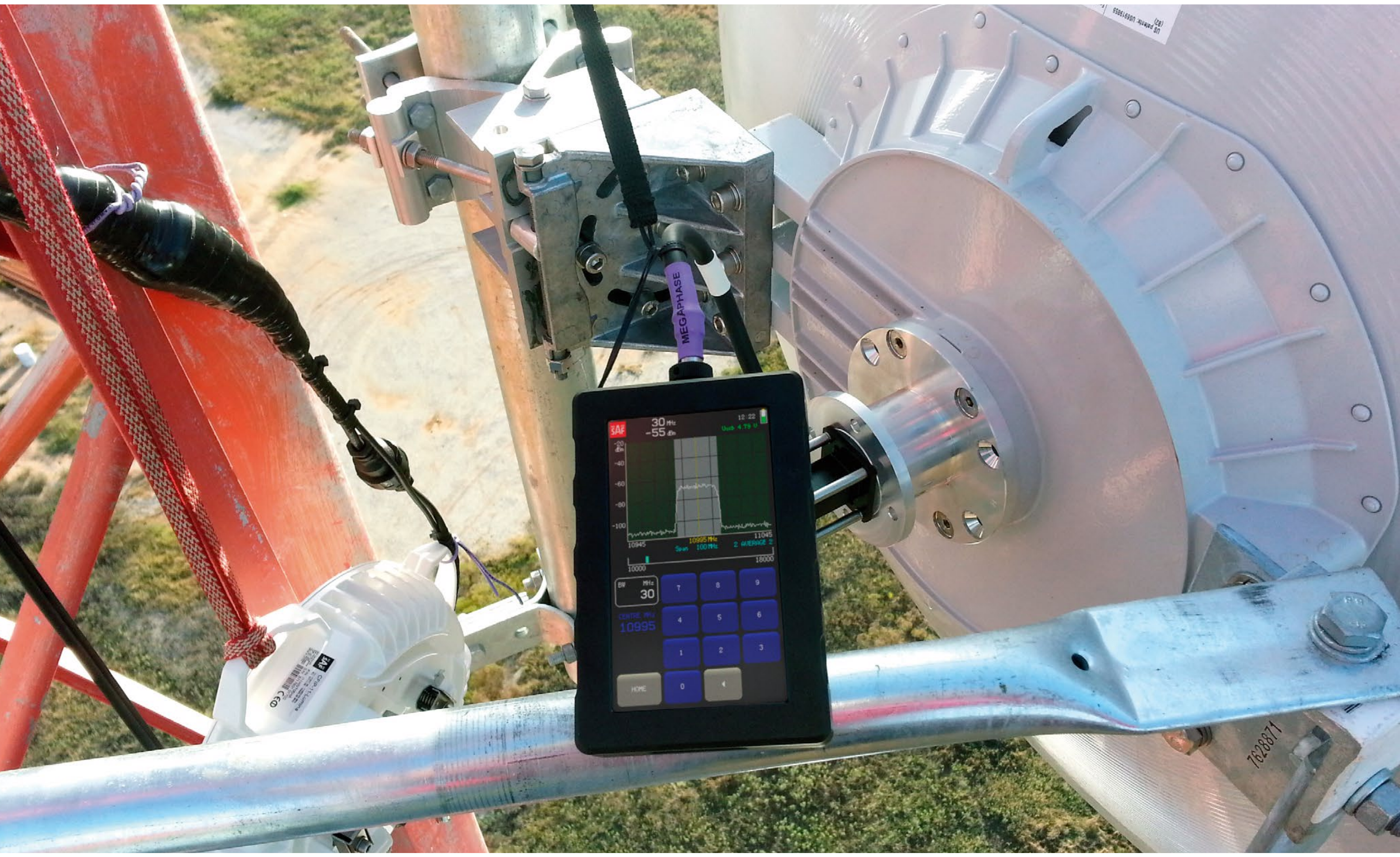



Fig. 3. Spectrum Compact connected to receiving antenna.

# Antenna Alignment Basics

Once both transmitter and receiver are mounted in the intended locations, the alignment process can begin. If antennas need to be aligned without having a transmitter on hand, tower crews can use the **SG Compact signal generator**, which can produce continuous wave (CW) signal at the required frequency.

Here are five tips to ensure accurate antenna alignment:

- **Team Approach** – Make sure to use a team at each end of the link to make alignment easier and faster. The receiving-end team will use the Spectrum Compact and give instructions to the second team located at the transmitter end. An established communication channel between both teams is mandatory.

- **One-At-A-Time** – The adjustment is performed only at one side of the link at a time, even if it seems advantageous to make it quicker by involving both teams in the adjustments. Trying to adjust both ends simultaneously will lead to a chaotic process that takes longer than necessary.

- **Disable ACM and ATPC** – Alignment should start with the ACM and ATPC disabled on transmitting radio. Once calculated signal value is achieved, users can enable ACM and ATPC.

- **Overcome Weak Signals** – If there is difficulty locating the signal, users can initially align antennas while using transmitter configuration of minimum modulation and bandwidth to achieve maximum Tx power. This can happen if the link design expects a weak incoming signal. Once the initial configuration is complete, set the required configuration, and proceed with further calibration.

- **Start with Antenna Polarization** – Agree on antenna polarization before beginning the alignment. It can be frustrating to attempt aligning the antenna only to discover that other team members are using a different polarization. If Rx levels remain stubbornly low, double check polarizations on both ends. Radios installed with incorrect polarizations may have a signal loss of 20 - 30dB or greater. Note: SAF Tehnika 17/24 GHz unlicensed band radios utilize a cross-polarization approach, where each side of the link transmits in the opposite polarization.

Field part of antenna alignment can be perceived as a two-stage process:

1. Initial **coarse alignment**
2. Further **fine alignment**

# Coarse Antenna Alignment

Coarse antenna alignment is an obvious concept – antennas should be facing one another *(Fig. 4)*. There are other considerations, as well.

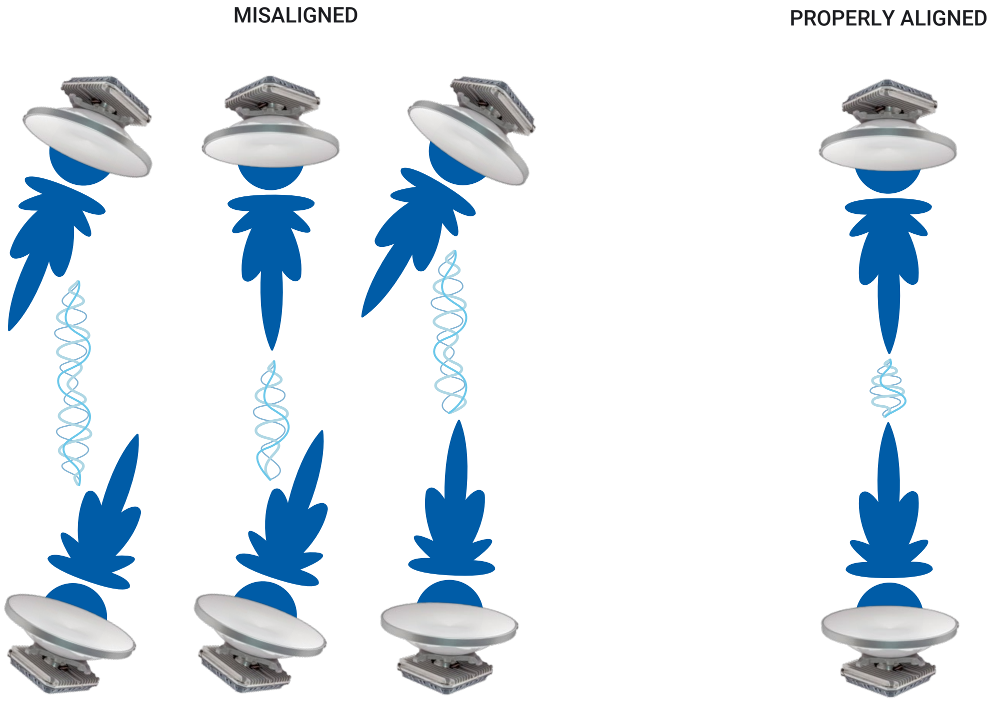



Fig. 4. Antenna alignment scenarios.

Point-to-point systems must have a clear radio line-of-sight. Even if the remote site has clear eye visibility, 60% of the radio signal's propagation depends on the **first Fresnel zone**. The Fresnel zone for a radio beam is an elliptical area immediately surrounding the visual path *(Fig. 5)*. It varies in width depending on the length of the signal path and the frequency of the signal. If an object, such as a mountain ridge or building, is too close to the signal path, it can reduce radio signal strength. The result is the desired Rx level will not be achieved. This happens even though the obstacle does not obscure the direct, visual line-of-sight. The necessary clearance for the Fresnel zone can be calculated, and it must be considered when designing a link.

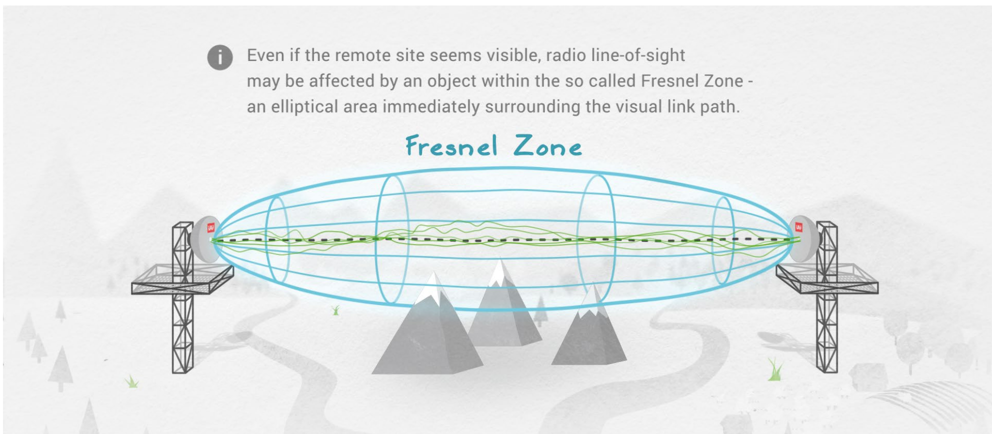



Fig. 5. Geometry of the Fresnel zone.

It is recommended to begin with **vertical alignment**. Using a level tool, set both antennas to null position vertically. This will ensure a better starting point for long links with limited eye visibility typically requiring large diameter antennas with narrow beamwidths.

Once the antennas are set to the same vertical level, proceed with **horizontal alignment**. First, set the antenna to the correct azimuth using a compass or GPS (note the difference between true and magnetic azimuth). Azimuth angles should be known from a link planning report. When using a compass, be aware that large metal structures, such as towers, may distort compass readings.

Alternatively, position the antenna's approximate horizontal direction by using Google Earth (or equivalent) to align with a landmark located close to the antenna. Examples include a mountain, building, and similar. If a link is being deployed in an area with a few landmarks, use a self-made landmark such as a kite, balloon, floodlight, flare, or reflection from a mirror.

Once the antenna is aligned using those steps, users should be able to catch the signal at the receiving end of the link with the Spectrum Compact connected to the antenna. Check to ensure the center frequency and bandwidth of the signal aligns with those that the team on the transmitting end have set up. To do this, use the same Spectrum Compact configuration as the one used during troubleshooting. Once completed, fine alignment can be conducted.

# Fine Antenna Alignment

A key characteristic of an antenna is its radiation pattern. It describes how the antenna will transmit the signal spatially. Looking at the radiation pattern, it's clear that the signal propagates in multiple paths (directions), called lobes. The lobes are radiation pattern angles and directions where the radiated signal strength reaches a maximum, separated by "*nulls*" – angles at which the radiation falls to zero.

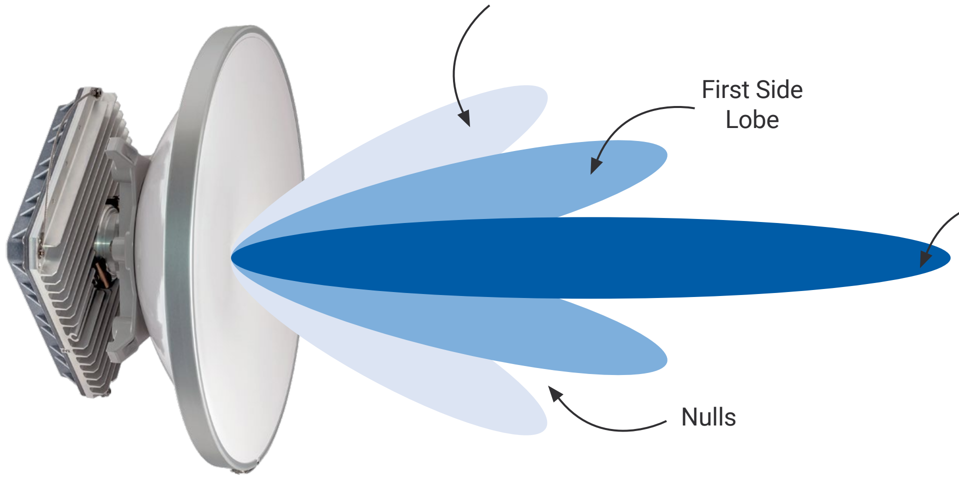



Fig. 6. Side view of the signal propagation

Each antenna has a main lobe and several side lobes *(Fig. 6)*. The difference in signal levels between the main lobe and the first side lobe is typically around 20dB. This, of course, varies with antenna size, frequency, and class. Small antennas in a low-frequency range typically have strong side lobes, which sometimes results in installation crews aligning the antenna on a side lobe instead of the main lobe.

When analyzing the signal frontally, the pattern in which the signal arrives consists of concentric circles *(Fig. 7)*. The main beam sits in the center and each next lobe is a circle with progressively larger diameters separated by nulls of the signal.

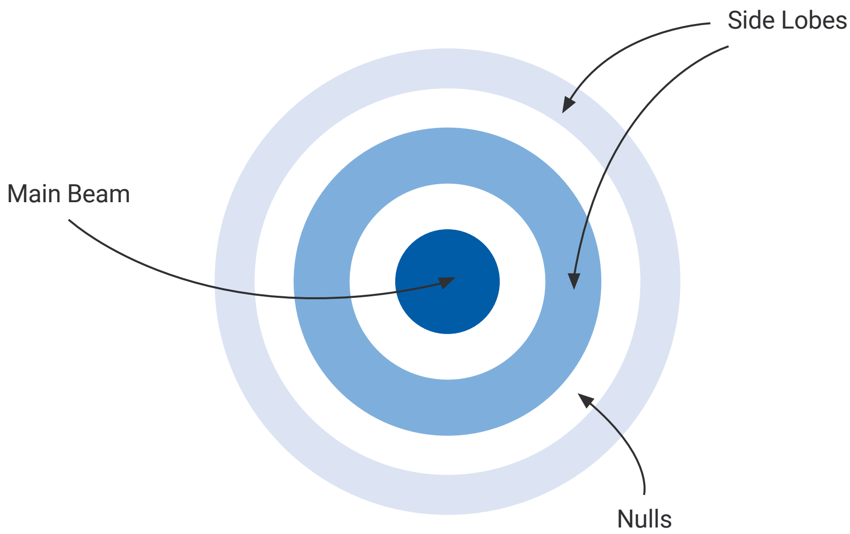



Fig. 7. Front view of the signal propagation

When an antenna sweep is performed and an initial signal is found, installers typically use the first signal and do not continue the antenna sweep *(Fig. 8)*. If this initial signal happens to be a side lobe, the antenna will most likely be aligned to it, resulting in poor link performance.

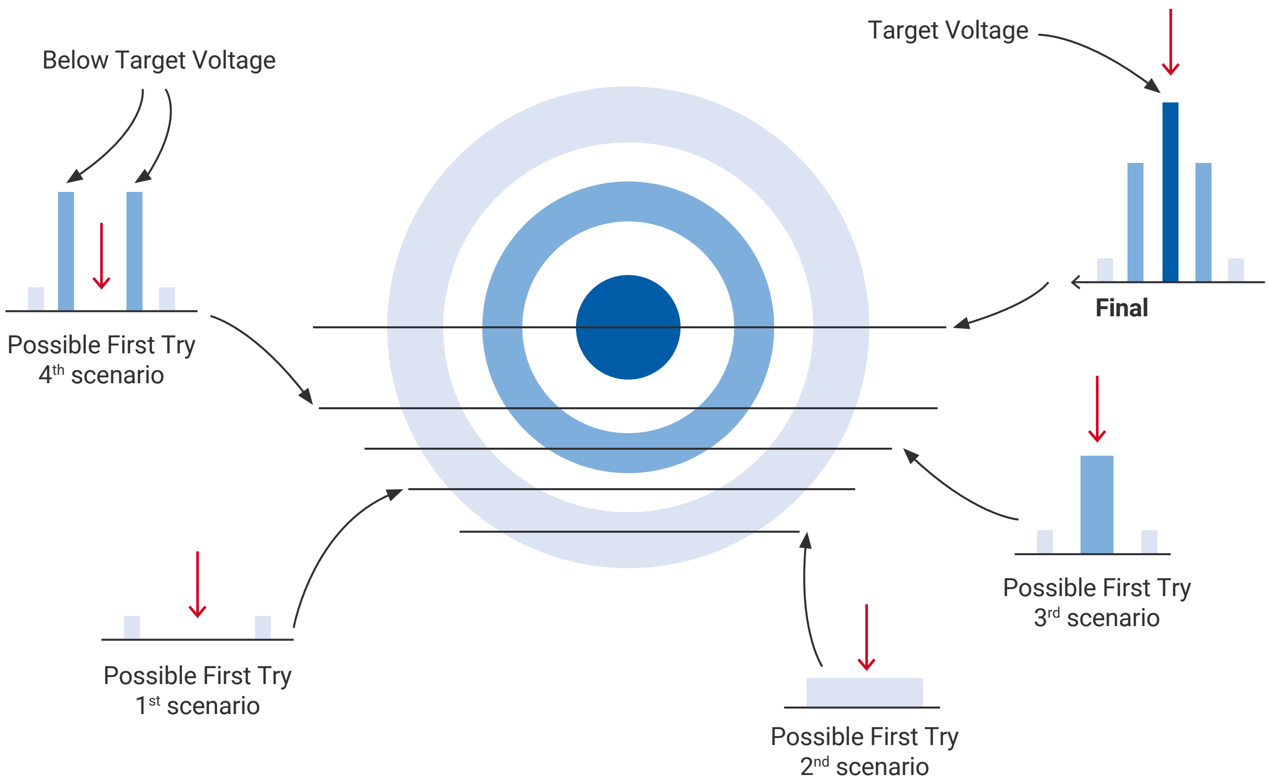
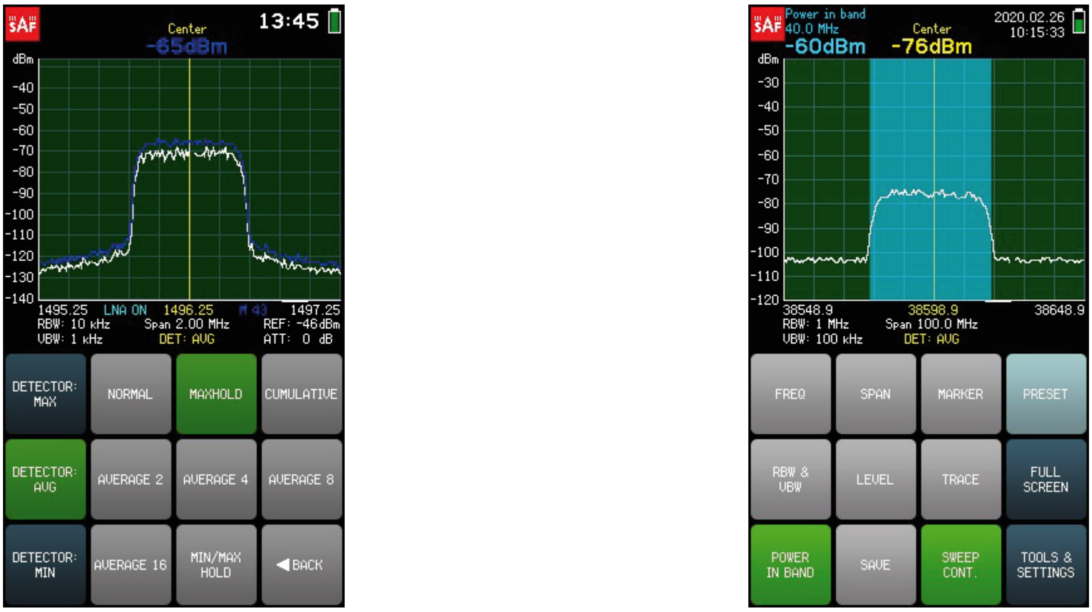



Fig. 8. Possible alignment outcomes in the horizontal plane.

Precise antenna alignment can be achieved using two Spectrum Compact functions – “*MAX Hold*” tracing and “Power in Band” integral measurement. Each can be further subdivided into alignment of the receiver and transmitter antennas. Full schema of the process can be seen in *figure 9*.




**MAX Hold** → **Power in Band**

| MAX Hold | Power in Band |
|---|---|
| **Receiving Antenna:** | **Receiving Antenna:** |
| 1. Vertical Aligment | 1. Vertical Aligment |
| 2. Horizontal Aligment | 2. Horizontal Aligment |
| **Transmitting Antenna:** | **Transmitting Antenna:** |
| 1. Vertical Aligment | 1. Vertical Aligment |
| 2. Horizontal Aligment | 2. Horizontal Aligment |

Fig. 9. Spectrum Compact functions aid in precise antenna alignment.

# MAX Hold Alignment

To find the main signal, field crews will perform antenna sweeps with Spectrum Compact attached to the receiver. "*MAX Hold*" saves the maximum level of signal achieved through a series of measurements. This will allow users to record the moment the main signal is designated, setting a benchmark for the sweep.

*Figure 10* is a Spectrum Compact display. The blue line indicates the maximum signal level achieved during a series of measurements. Once users can no longer raise the signal level any higher, the benchmark needed to replicate is achieved, allowing the antenna to be secured in that position.

A full vertical sweep is conducted by moving the antenna of the receiving side up and down. Move the antenna from the uppermost position to avoid accidentally aligning the antenna to a signal reflected from the ground. Fix the antenna on the direction where the highest signal level is indicated – the actual signal level must match with the "*MAX Hold*" maximum recorded signal level.

The next step is performing the same procedure but in the horizontal direction. The same principle applies – produce a maximum level benchmark using "*MAX Hold*" indications, then replicate it via antenna adjustment.

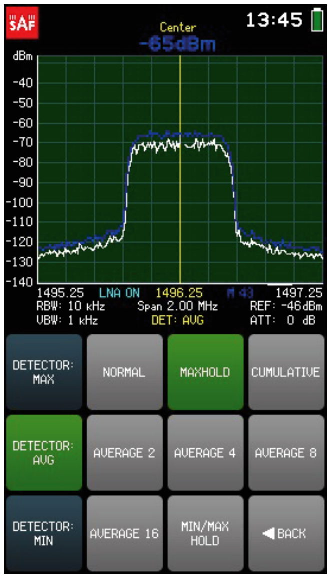



Fig. 10. Example of maximum signal tracing with Spectrum Compact. Blue line depicts maximum achieved through series of measurements.

When the highest signal level is obtained during the alignment of the first antenna, adjust as necessary. The other team can start antenna alignment by repeating the same steps with the second antenna. Note that the signal level must be monitored on the same Spectrum Compact spectrum analyzer locally. The remote team must be instructed via direct communication about the antenna sweeping process by the lead team based on the readings on the Spectrum Compact.

# Power in Band Alignment

After determining the highest signal level on the second antenna, disable "*MAX Hold*" and enable the "*Power in Band*" on the Spectrum Compact. This function will indicate actual Rx signal level based on the channel bandwidth.

It is essential to make sure the correct Rx frequency and channel bandwidth are set in "*Power in Band*" mode. Then a light blue band *(Fig. 11)* will appear. This is the bandwidth in which the power will be measured.

The goal is to have the light blue number in the top left corner be the highest possible value. Users can configure Spectrum Compact to repeat steps performed during "*MAX Hold*" alignment:

1. Receiver antenna alignment: first vertical, then horizontal
2. Transmitter antenna alignment: first vertical, then horizontal

Through this method, users should be able to reach the maximum calculated signal level with the precision of +/-3dBm.

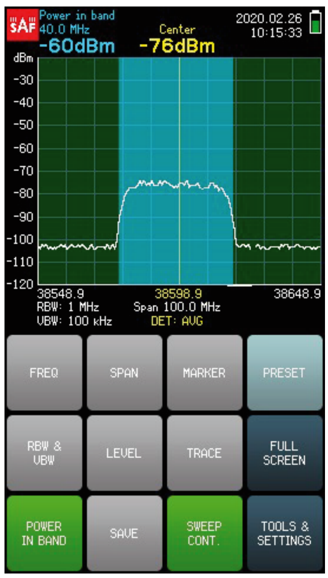



Fig. 11. Example of power in band measurement with Spectrum Compact. Light blue area indicates frequency span over which amplitude of signal is integrated.

# Signal Analysis

Field crews can conduct signal analysis after collecting all the measurements. The first step is to check the signal shape displayed in the Spectrum Compact. Save the signal spectrum curve for the report to better communicate link data with colleagues to predict potential issues. If everything is within specification, then it will serve as the proof of correct signal at some point before problems occur.

If the signal shape is damaged or the top of the signal is "*wavy*," troubleshooting should be performed. Damage can be the result of the antennas being aligned based on the reflected signal. It may also be due to possible interference from reflective planes, such as rooftops or lakes in the middle of the path, especially for short link alignment in urban areas. To avoid this condition, always start vertical alignment sweeps from the uppermost position; the antenna should be aligned "*into the sky*" at the onset. If the antenna is aligned on the reflected signal, the signal shape will be "*wavy*" and possibly fluctuating – those effects are easily detectable with Spectrum Compact.

In case of two approximately equal signal peaks during the vertical sweep, it is most likely that a side lobe has been found in the current adjustable plane *(Fig. 4, 4th and 1st scenario)*. Aligning precisely on one of those peaks may result in an improper overall alignment result. Field crews should aim in the middle between those two peaks, switch the alignment plane to the horizontal plane and perform the sweep. Once the main signal in the horizontal plane is found, return to the vertical plane, and proceed with alignment.

# Notes

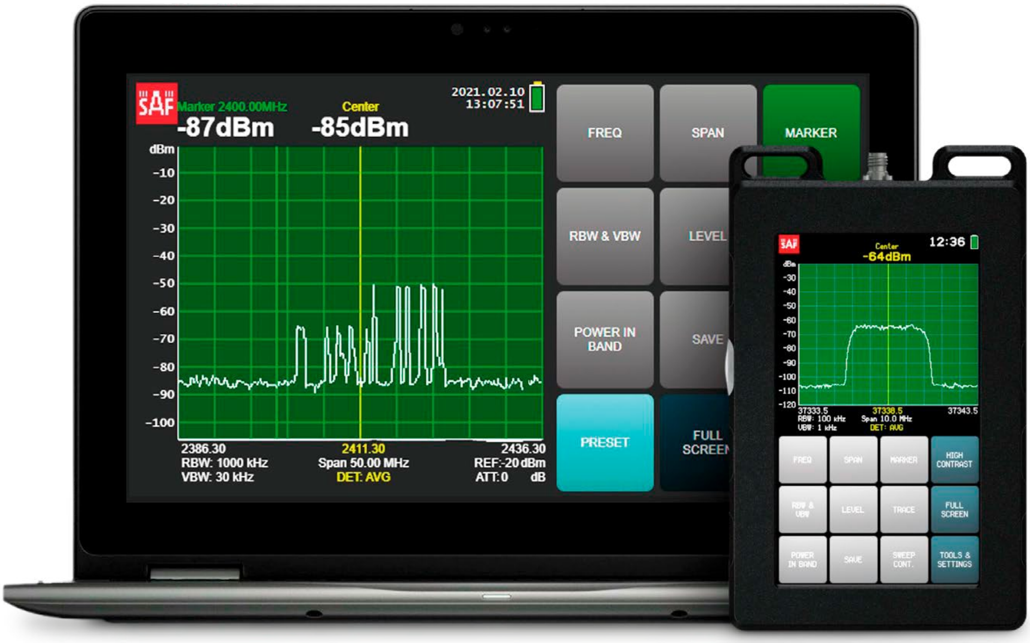
- The type of antennas being aligned must be factored to achieve fine alignment:
  - Antennas sized up to 1.2m have a wider main beam and more evident side lobes.
  - Bigger antennas with a higher gain have a narrow main beam and less relevant side lobes.
- If there are problems capturing weak signals, use a slightly different setup. Connect the Spectrum Compact horn antenna to the Spectrum Compact spectrum analyzer rather than to the big antenna. The horn antenna has wider beamwidth to "*catch*" the signal faster. When the signal is detected, aim the big antenna to the same direction as the horn antenna.

# Conclusion

Using a handheld spectrum analyzer for antenna alignment is a necessity to ensure each alignment is done in the most cost- and time-efficient manner. The amount of information acquired when looking at the signal in the frequency domain gives users the ability to make informed decisions. Some of this information – frequency of interference source, shape of the received signal, "*shakiness*" of the signal's amplitude – is simply inaccessible without using a spectrum analyzer.

Training field crews how to use a spectrum analyzer is rather easy, especially the Spectrum Compact. Users can simply access the analyzer's full power through its transparent, intuitive interface. Combining this with robustness of the device, makes it the perfect tool, regardless of the field technician's experience in RF engineering.

Antenna alignment is a clear example of how a spectrum analyzer is advantageous in more than conventional applications. Visit **SpectrumCompact.com** to learn how to use the handheld spectrum analyzer for antenna alignment, point-to-point link setup, indoor signal mapping, satellite communications, and more.

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References:

*Spectrum Compact: https://spectrumcompact.com/spectrum-compact/*
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*Online Spectrum Compact Demo: https://spectrumcompact.com/emulator/*
*Antenna Alignment Video: https://www.youtube.com/watch?v=rwknnDBFM8U*
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