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GX4000 E-Band Millimeter-Wave Radio Delivers Secure Fixed Wireless Communication

Network operators and service providers seeking to increase data communications traffic are likely to encounter situations and locations where fiber is not an option. Consequently, there is growing demand for higher-capacity radio transmission.

Meeting this demand using conventional technology requires a wider frequency band and multiple radio channels. Unfortunately, this solution is infeasible both economically and practically.

A number of fixed wireless alternatives, however, are available.

Several high-capacity data transmission applications are being deployed using fixed wireless links over short distances. These have proved to be suitable alternatives to fiber.

Fixed wireless communication in the E-band spectrum is increasingly attractive, since the fundamental characteristics of E band make it less susceptible to distortion, interference, and security breaches. Available today are a number of fixed wireless data transmission technologies in the E band.

Among the conventional techniques for modulating data signals onto a carrier are On-Off Keying (OOK), Frequency Shift Keying (FSK), Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), and Quadrature Amplitude Modulation (QAM).

Fujitsu Impulse Radio Technology

Alternatively, the Fujitsu GX4000 E-band radio uses impulse radio (IR) technology. This technology uses a transmission method that sharply contrasts with conventional QAM modulation. In IR transmission, impulse signals corresponding to input bits are transmitted by ultrashort pulses. The pulses are wideband-amplified and filtered to extract the transmitted E-band spectrum corresponding to the input signals. On the receive path, an innovative wideband low-noise and low-distortion envelope detector extracts the data. The IR transmit and receive paths use a simple pulse generator, wideband amplifiers, wideband filters, and an energy envelope detector.

Figure 1 depicts the impulse radio filter bandwidth. Figure 2 depicts the impulse radio waveform.

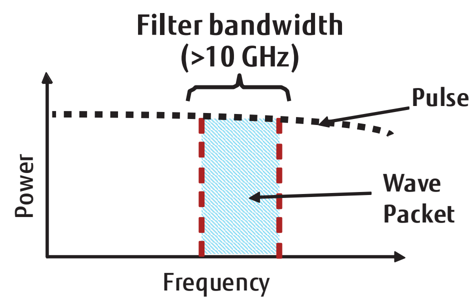


Figure 1: Impulse radio filter bandwidth

- ON/OFF Modulation, Envelope Detection
- Throughput ~ Filter Bandwidth (10 Gbps ~ 10 GHz)

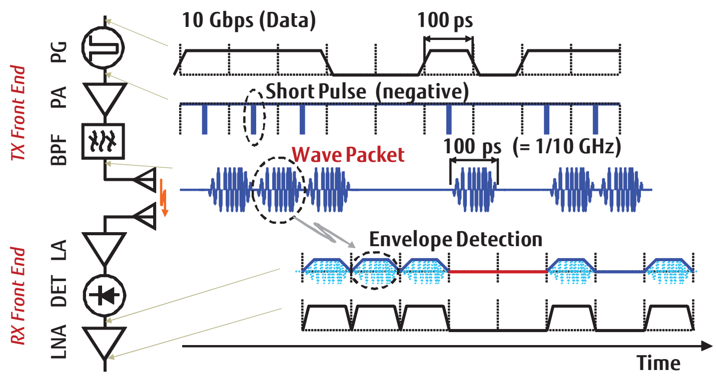


Figure 2: Impulse radio waveform

Fujitsu uses innovative IR technology to derive a wideband front end to serve the needs of a growing, high-capacity multiradio environment.

A millimeter wave–based technology employing bidirectional pencil-like beam signal characteristics (Figure 5) transmits and extracts E-band wave packets from the frequency domain, eliminating spurious emission, and keeping distortion low for minimal interference.[1]

GX4000 E-Band Security

The GX4000 uses patented Fujitsu IR modulation technology that differs dramatically from conventional modulation, such as QAM. Five factors make the E-band solution more secure from security breaches:

- Units can be installed along the same axis within 3 degrees of one another and with 1 meter of separation in an N+0 configuration
- The unique IR-received RF signal cannot be demodulated or decoded by a QAM-based radio (Figure 4)
- Sharp beam characteristics (Figure 5)
- The GX4000 uses a Fujitsu-patented framing process
- The IR function is based on a patented, Fujitsu-developed CMOS device

The GX4000 security access mechanism uses network address filtering without blocking routing across the GX4000. Users define an access list that filters network addresses and blocks unlisted remote radios. If the equipment's intrusion detection threshold is crossed, the user session is closed and access is blocked.

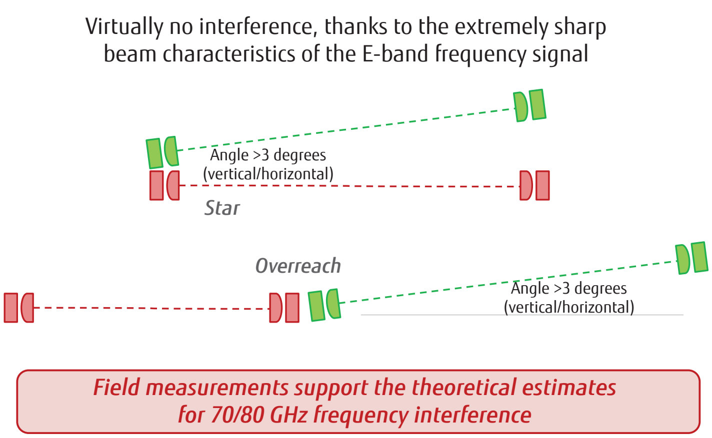


Figure 3: Sharp beam characteristics provide the interference rejection properties of the GX4000

Because of the nature of 70/80 GHz signal beam, the direct and sharp radiation pattern of the antennas, and GX4000 impulse radio technology, there is essentially no chance of decoding or descrambling the IR signal. The GX4000-received RF signal cannot be demodulated or decoded by a non-Fujitsu radio, as the GX4000 uses a Fujitsu-patented framing process.

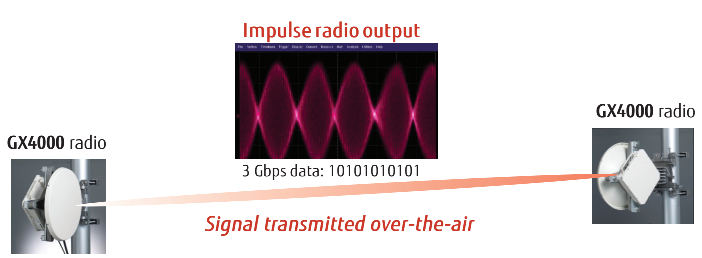


Figure 4: Impulse radio waveform

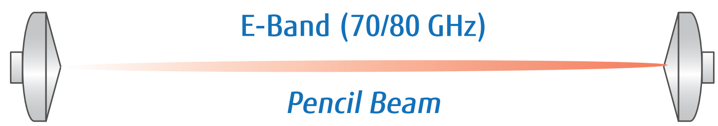
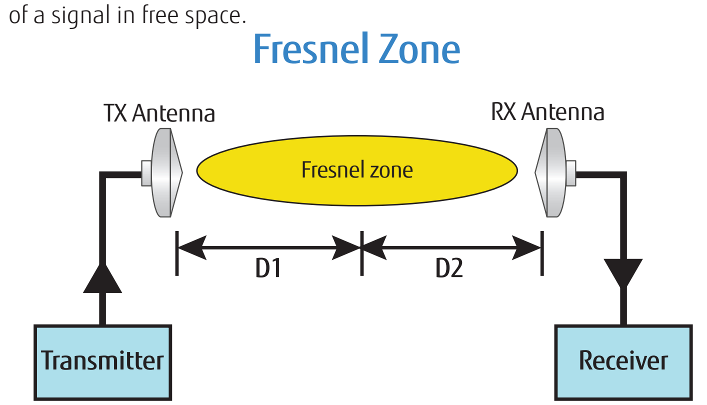


Figure 5: 70/80 GHz E-band millimeter waveform has sharp beam characteristics

Fresnel Zone Clearances

The Fresnel (fray-NEL) zone is a circular area perpendicular to and centered on the line of sight. In radio wave theory, if 80% of the first Fresnel zone is clear of obstacles, wave propagation loss is equal to that of a signal in free space.



$FZ = 72.1 \times \sqrt{(D1 \times D2)/f \times Rm}$

FZ = radius of Fresnel zone in feet from direct line of sight

$D1$ = first distance to obstruction in miles

$D2$ = second distance to obstruction in miles = $Rm - D1$

f = frequency in gigahertz

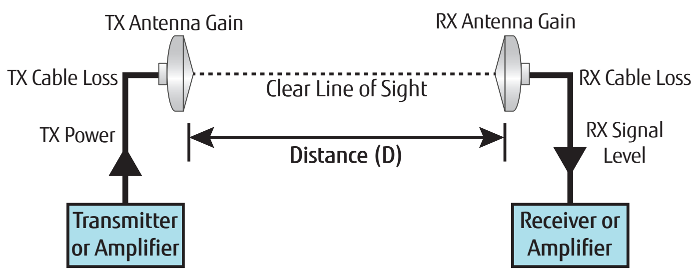
Rm = distance between antennas in miles

Figure 6: Fresnel zone calculations of a path

Free Space Loss

Free space loss is defined as the loss in signal strength of an electromagnetic wave that would result from a line-of-sight (LOS) path through free space (usually air), with no obstacles nearby to cause reflection or diffraction. In "Standard Definitions of Terms for Antennas," IEEE Standard 145-2013, free space loss is defined as "the loss between two isotropic radiators in free space, expressed as a power ratio." Free space loss usually is expressed in decibels (dB).

Free Space Loss



Receiver Sensitivity (RX) = TX Power – TX Cable Loss + TX Antenna Gain – Free Space Loss (Clear Line of Sight) + RX Antenna Gain – RX Cable Loss

RX Signal Level = TX Power – TX Cable Loss + TX Antenna Gain – Free Space Loss + RX Antenna Gain – RX Cable Loss

Figure 7: Free space loss calculations

Antenna Radiating Pattern

Figure 8 shows the typical radiating pattern of a 1-foot antenna, the FCC spectrum mask, and the signal attenuation that occurs moving from the center or main lobe. The GX4000 operates without interference within 1 meter of another GX4000 radio. Note the 50 dB drop from the center lobe signal. Factoring in the free space loses from the originating site, the TX signal will be far too weak for a 10^{-6} bit error rate (BER) link to pass traffic.

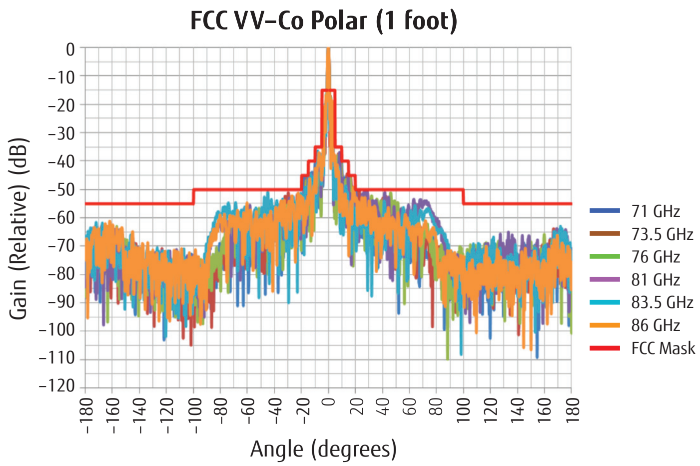


Figure 8: Typical radiating pattern of a 1-foot antenna

Consider these parameters to secure networks using the E-band millimeter-wave radio platform:

- For the 70/80 GHz band, it offers a lightly licensed spectrum. The 60 GHz band is licensed exempt.
- Narrow beam–width antennas make for near interference-free operation:
  - 1-foot antenna: 0.9 degree beam
  - 2-foot antenna: 0.5 degree beam
- Proprietary protocols running between the radio link
- Association as primary/secondary radio identification
- Unique qualifiers such as Link ID numbering
- Firmware and configuration must match both ends to pass traffic
  - Traffic port configuration
  - Management configuration as inband or out of band for both ends of the link
- Alignment on the center lobe of the antenna for maximum Receive Signal Level (MAX RSL) value

If an attempt were made on a Fujitsu GX4000 link using another GX4000 radio, it would have to meet all the requirements described previously and be installed to detect the TX signal greater than 10^{-6} BER for a passing RF link quality. Figures 9 and 10 provide examples.

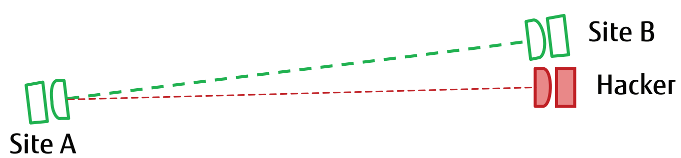


Figure 9: Radio attack 1

In Figure 9, Site A is passing traffic to Site B. An attempt begins when a hacker radio is introduced to the RF path. If the hacker radio is configured the same as Site B as well as associating to Site A with an RSL value greater than threshold (–53 dB) and a link quality greater than 10^{-6} BER, traffic could pass.

As illustrated in Figure 8, the signal strength will be down at least 50 dB from the center lobe, making it difficult to obtain the RF parameters necessary to establish a traffic-passing link.

Figure 10: Radio attack 2

In Figure 10, Site A is passing traffic to Site B. An attempt begins when a hacker radio is introduced to the RF path. If the hacker radio is configured the same as Site B as well as associating to Site A with an RSL value getter than threshold (–53 dB) and a link quality greater than 10^{-6} BER, traffic could pass.

The hacker radio in this illustration will have a difficult time associating with the Site A radio because of the proximity of the Site B radio. Referring to Figure 6 and the definition of the Fresnel zone, the closer an object or obstruction is to one end increases the unlikeness to communicate to the opposite end of a link. This is due to the link's high diffraction loss or increased free space loss.

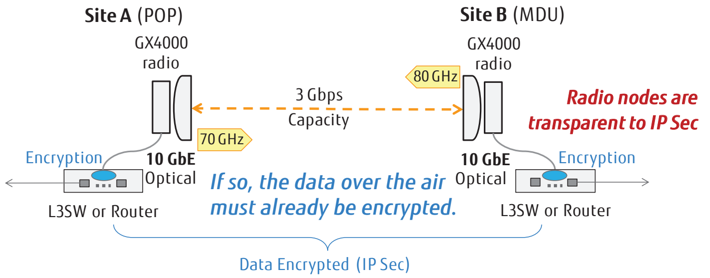


Figure 11: Encryption over the air versus an optical cable

Therefore, other radio receivers cannot descramble the signal. The over-the-air transmitted signal has no chance of being decoded or descrambled. When fiber is used instead of an E-band over-the-air application, encryption technology should be incorporated in the devices to secure the link.

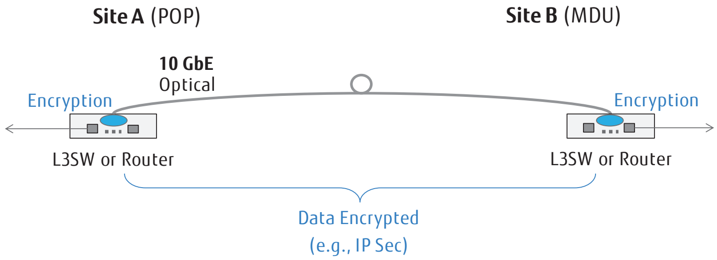


Figure 12: Encryption over an optical cable

Conclusion

Fujitsu impulse radio technology provides security advantages over QAM methods. The Fujitsu GX4000 offers extremely high throughput, high security reliability, and low energy cost in a compact platform designed to meet the demands of today's networks without the need for additional encryption devices.

References

1. Millimeter-wave Impulse Radio Technology, Fujitsu Scientific & Technical Journal, Vol. 49, No. 3, pp. 350–355 (July 2013); H. Hayashi

2. Evaluating Fixed Wireless Data Transmission Options within the E-Band, O. Adeyemi (November 2014), http://www.fujitsu.com/downloads/TEL/fnc/whitepapers/Evaluating-E-band-Wireless.pdf

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