Spread Spectrum Rule Recommendations

Phil Karn, KA9Q

What Is Spread Spectrum?

- ***ANY*** **communication system that uses much more RF bandwidth than baseband bandwidth**
- **Not really limited to “traditional” SS systems, e.g., direct sequence, frequency hopping, etc**
- **Includes “narrowband FEC” systems**
- **Arguably applies to ordinary analog FM!**

Why Use Spread Spectrum?

- **For the same reasons we use FM! And more**
- **Interference and noise rejection ("capture effect"). 10dB for FM; digital SS systems have *negative* capture ratios (e.g., -15 dB)**
- **Simplifies spectrum management**
- **Highly effective against multipath fading**
- **Can dramatically *increase* capacity of spectrum in a frequency reuse environment**

Traditional Spectrum Management

- Bandwidth is precious - minimize its use
- Carve up the spectrum into channels and fight over them
- Give lip service to transmitter power control

Why The Tradition Is Wrong

- **Goes against well-established theory (Shannon, 1948)**
- **Users' demands are seldom constant - trunking inefficiencies and (re)allocation overheads are enormous**
- **In a frequency reuse situation (i.e., almost all of amateur radio), interference is a fact of life**
- **Increasing interference resistance *inherently* requires extra bandwidth**
- **Interference resistance wins out over extra bandwidth**

These Ideas Are Not New!

- **Shannon published theory in 1948**
- **John Costas (K2EN) published *Poisson, Shannon, and the Radio Amateur* in 1959: "The results ... challenge the intuitively obvious and universally accepted thesis that congestion in the RF spectrum can only be relieved by the use of progressively smaller transmission bandwidths..."**
- **What's new is the digital technology now available to us**

Why Should We Encourage Amateur Spread Spectrum?

- Because it exists, and we’re hams
- Because the rest of the world is rapidly embracing it (GPS, cellular phones, Part 15.247)
- Because shared, congested amateur bands are a fact of life, and we should encourage spectral efficiency

Can’t Nearby SS Stations Blanket a Whole Band?

- **Yes! But the same is true in practice for narrowband stations - ever tried to share 20m with the KW station next door?**
- **Efficient, power-controlled spread spectrum is actually a pretty benign neighbor**

Can’t a Whole Bunch of SS Stations Raise The Noise Floor?

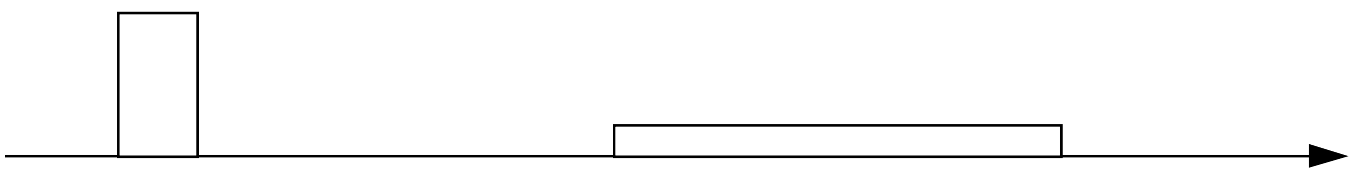
- Yes! But a whole bunch of narrowband stations can occupy every channel, which is even worse
- Our licenses do not guarantee us access to the spectrum at all times - it’s a dynamically shared resource, and sometimes the demand exceeds supply
- Spread Spectrum represents a way to increase spectral efficiency and thereby reduce the chance that demand will exceed supply

How Do We Promote Efficiency?

- **Encourage spread spectrum!**
- **Minimize *power,* not bandwidth**
- **CDMA cellular shows minimizing power is the key to maximizing spectral efficiency**
- **I.e., we should require automatic power control in amateur SS systems as a condition of relaxed bandwidth limits**
- **Repeaters and directional antennas also minimize power**
- **Other benefits: reducing RFI, biohazards, battery drain, etc**

Spread Spectrum Power

- By themselves, frequency hopping and direct sequence are "power neutral". Over a nonfading, white-noise channel, they use the same total power as a narrowband signal:

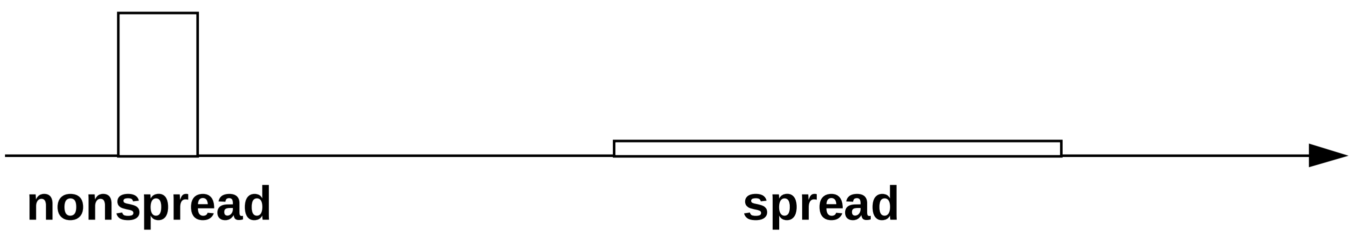


Spectral density (W/Hz) x Bandwidth = Total power
Same for both cases (equal areas)

-SS on fading channels needs less fade margin

Forward Error Correction

- **By adding FEC we can actually *reduce* the total power (E_b/N_0) to send at a given rate!**



area of spread signal now less than nonspread signal

-Think of “spectral density” as “QRM potential”

We now win twice from a QRM perspective:
first, because power is spread out thinly,
second, because there is less total power

What is E_b/N_0?

- The ratio of the received energy per bit, in watt-sec or joules, to the noise spectral density, in watts per hertz
- Equal to the S/N (signal-to-noise) ratio *only* when the bandwidth is equal to the data rate
  - S/N ratio depends on bandwidth and data rate
  - E_b/N_0 is independent of bandwidth and data rate
- The required E_b/N_0 is a modem's fundamental figure of merit - the lower the better
- Inversely proportional to capacity in a spread spectrum environment

Power Reduction with FEC

- **Forward Error Correction (FEC) coding, a basic part of all modern SS systems, actually *reduces* the power required to send at a given rate**
- **Gains of 7-10 dB are possible on nonfading channels, as much as tens of dB on fading channels and against interference**
- **FEC inherently requires extra bandwidth, making it “SS-like” without actually spreading**

Example: UHF Mobile

- Qualcomm CDMA (IS-95) digital cellular uses Direct Sequence Spread Spectrum on both forward and reverse links. 1.25 MHz BW
- The forward link uses BPSK data modulation with rate 1/2 FEC. Loose power control
- The reverse link uses 64-ary orthogonal data modulation with rate 1/3 FEC. Tight power control (+/- 1dB)
- Typical reverse link E_b/N_0: 5 dB in fading
- Typical mobile transmit power: 1-3mW!

Example: HF

- **HF simulator tests of Clover II vs STANAG 4285 (NATO standard military modem) by KE4BAD (QEX, Dec 1994)**
- **Clover uses a 500 Hz bandwidth; STANAG 4285 uses 3KHz**
- **Both are reasonably efficient systems within their bandwidth constraints; both significantly outperform uncoded FSK**
- **Clover requires at least 10 dB more E_b/N_0 than STANAG 4285 for the same error rate**

Recommended Rule Changes

- **Delete existing SS rules (97.311)**
- **Waive existing 97.307 bandwidth limits for stations that use less than 100W *and*:**
  - **Use less than 1W, *or***
  - **Automatically limit received E_b/N_0 at the intended receiver(s) to 20 dB**
- **Maximize flexibility - do not require any particular form of modulation, coding, etc, or mandate a minimum processing gain**
- **Resolve interference disputes in favor of the lower-powered station, regardless of mode**