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A Critique and New Concept on Gain Bandwidth Limitation of Omnidirectional Antennas

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Fractional Bandwidth Is Inadequate for Broadband Problems

- Electrical engineering (EE) in the past
  - deals with narrowband problems
  - uses fractional bandwidth (in %)
- Audio engineering
  - deals with ultrawideband problems
  - measures bandwidth in octaves
  - does not and cannot use fractional bandwidth
- EE is increasingly ultrawideband
  - fractional bandwidth not adequate
  - needs new measure for bandwidth

Various Definitions for Bandwidth

- Fractional Bandwidth B_f

$$B_f \equiv \Delta F / F_o \equiv (F_H - F_L) / F_o \qquad \text{(in \%)}$$
$$= 2 (F_H - F_L)/ (F_H + F_L) < 200\%$$

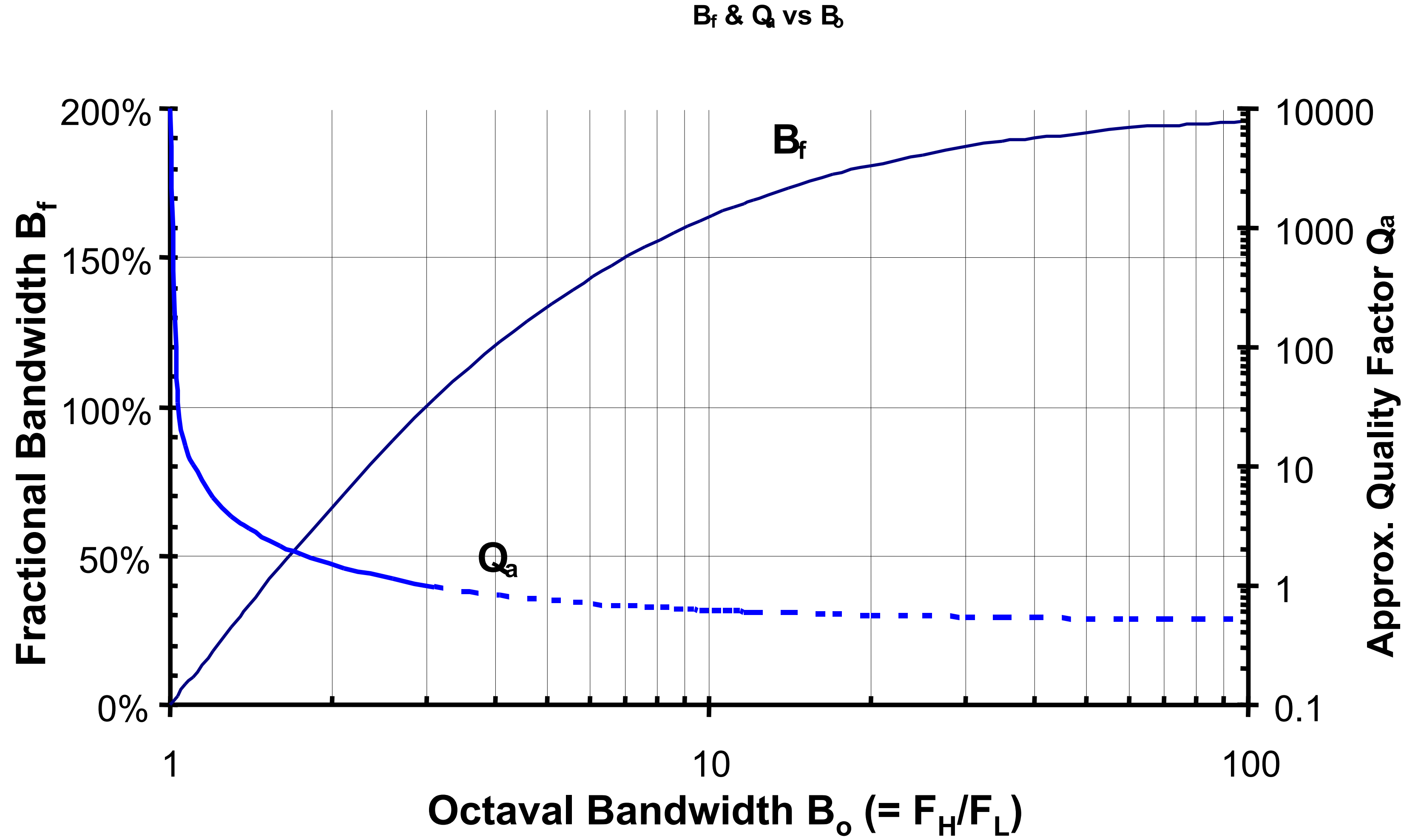
- Octaval Bandwidth B_o (a new definition for EE)

$$B_o \equiv F_H / F_L \qquad \text{(In unit like the SWR)}$$

- Relation between B_f and B_o

$$B_f = 2 (B_o - 1)/ (B_o + 1)$$

Octaval Bandwidth B_o, Fractional Bandwidth B_f, and Approximate Quality Factor Q_a



What Is the Bandwidth of an Antenna?

- Dependent on the performance criteria
  - gain (minimum peak gain, minimum gain in spatial coverage, etc.)
  - Pattern or directivity
  - maximum sidelobes
  - SWR, efficiency
  - system performance (diversity gain, etc.)
- Dependent on definition of bandwidth
  - Fractional bandwidth
  - Octaval bandwidth (NEW!)

Fractional or Octaval Bandwidth?

- Fractional bandwidth
  - Suitable for resonant antennas
  - NOT suitable for non-resonant antennas such as
    - Frequency-independent antennas
    - Broadband traveling-wave antennas
- Octaval bandwidth
  - Suitable for both resonant and non-resonant antennas

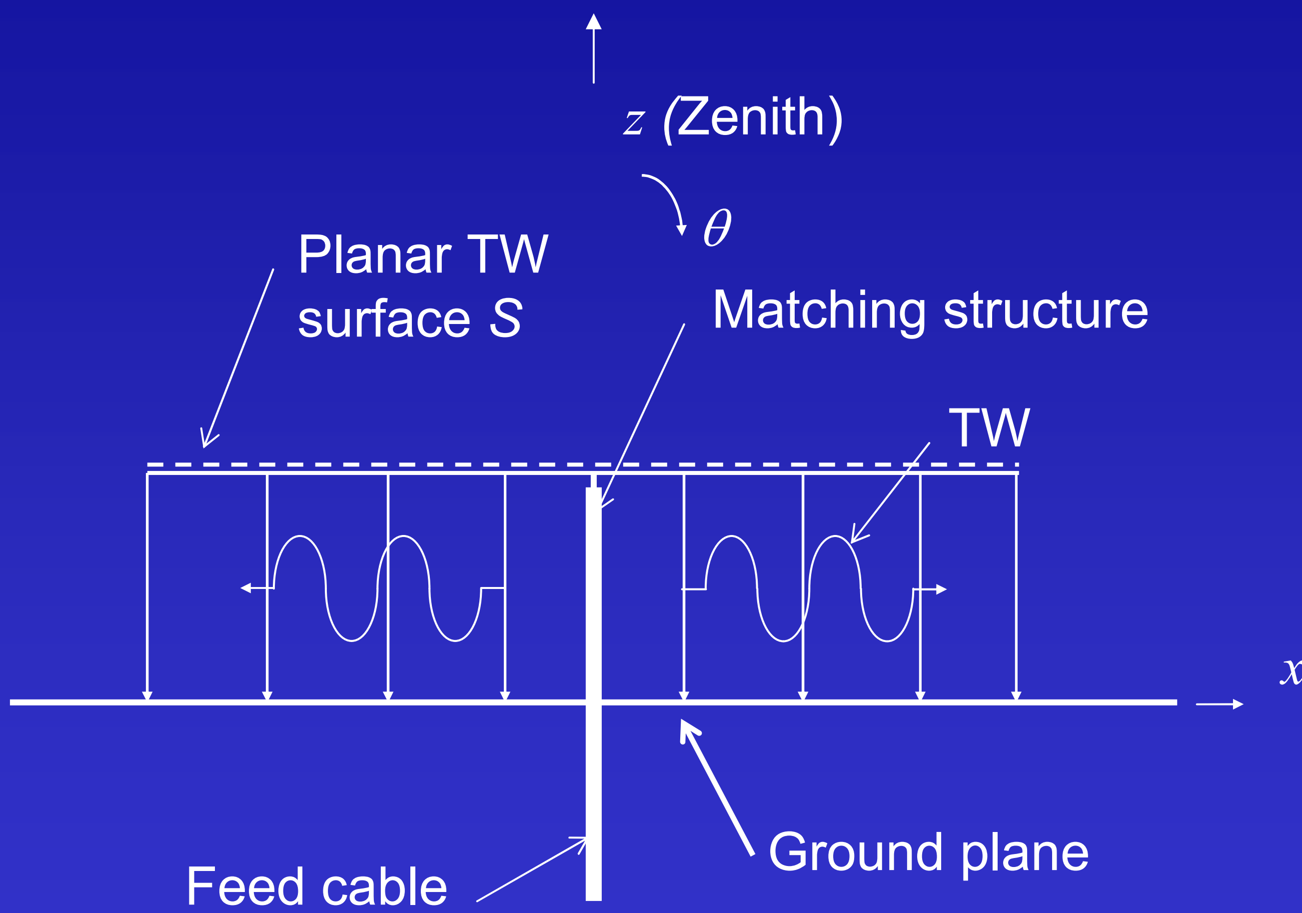
The Chu Theory on Gain Bandwidth of Antennas Is Too Narrow

- Zero dissipative loss assumption
- Single-port impedance
  - not characteristic of non-resonant antennas
  - Based on Q and fractional bandwidth
- Not suitable for non-resonant antennas
- $B_f \sim 1/(2\ Q_a)$ is valid only for $Q_a > 4$
- Antenna performance criteria too narrow

A 1-10 GHz Mode-0 SMM Antenna

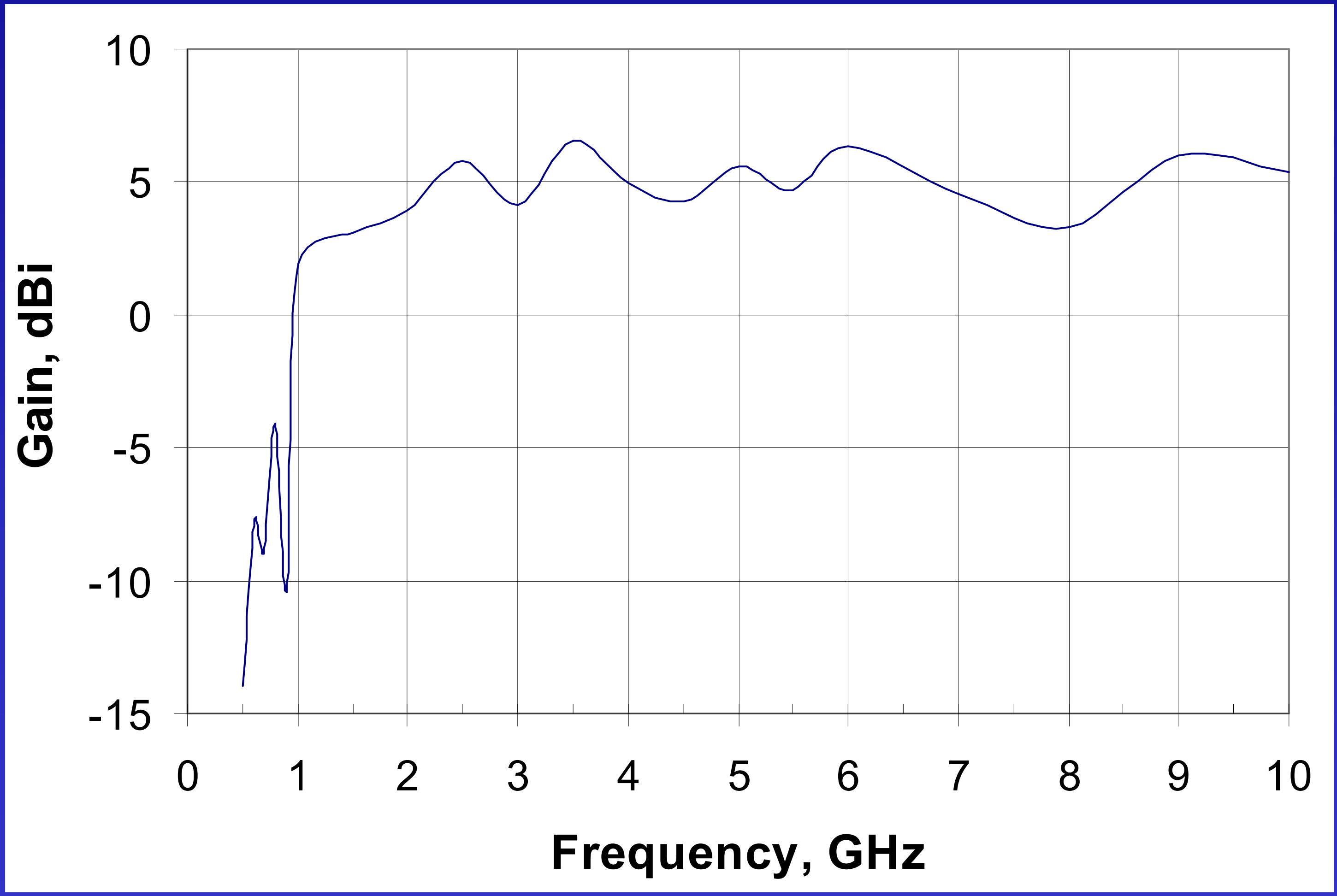
WEO Model SMM-1G10G-0-

An Omnidirectional Conformable TW (Traveling Wave) Antenna

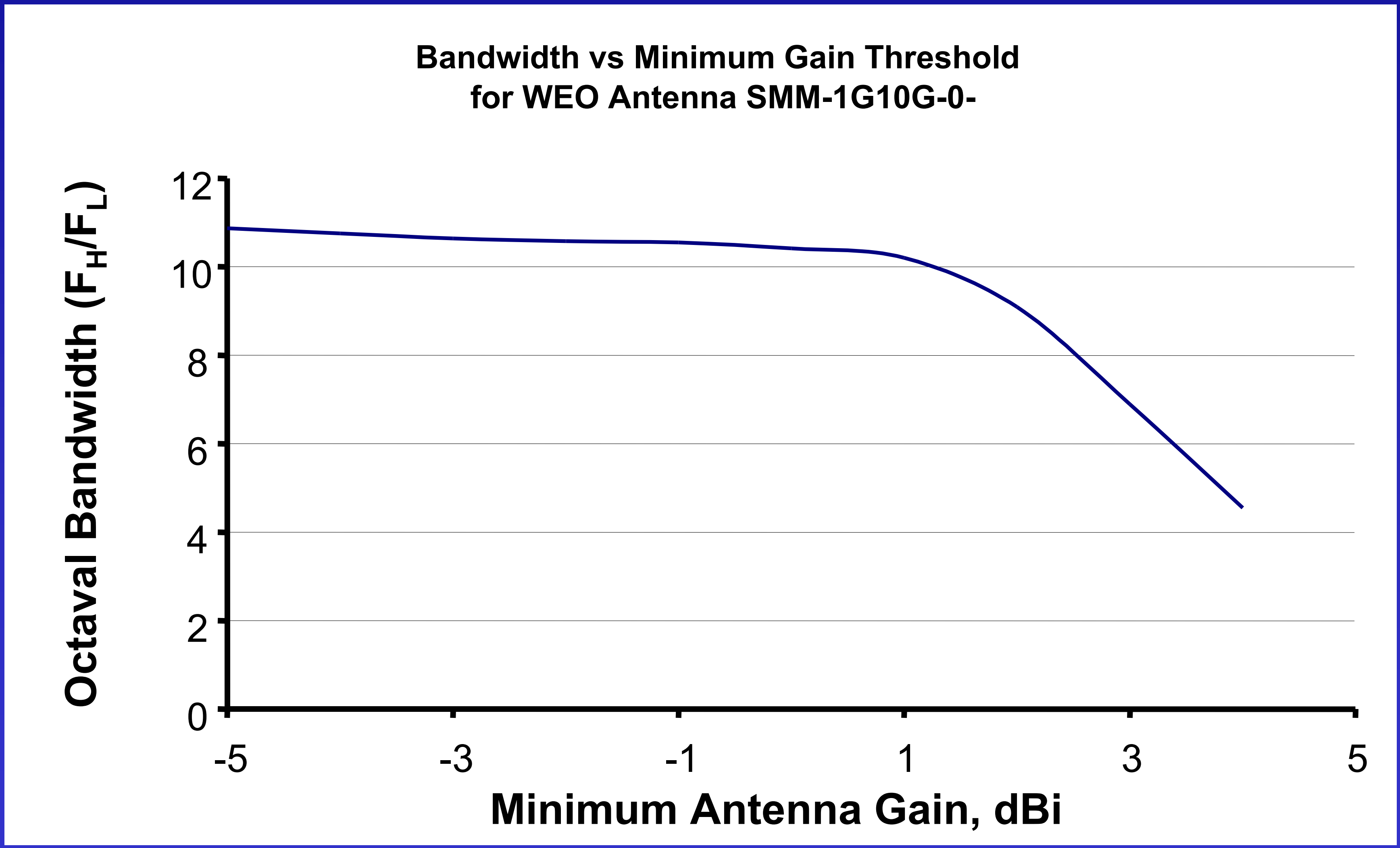


Measured Gain of an Omnidirectional TW (Traveling Wave) Antenna

WEO Model SMM-1G10G-0-



Octaval Bandwidth of a Wang Omnidirectional Antenna



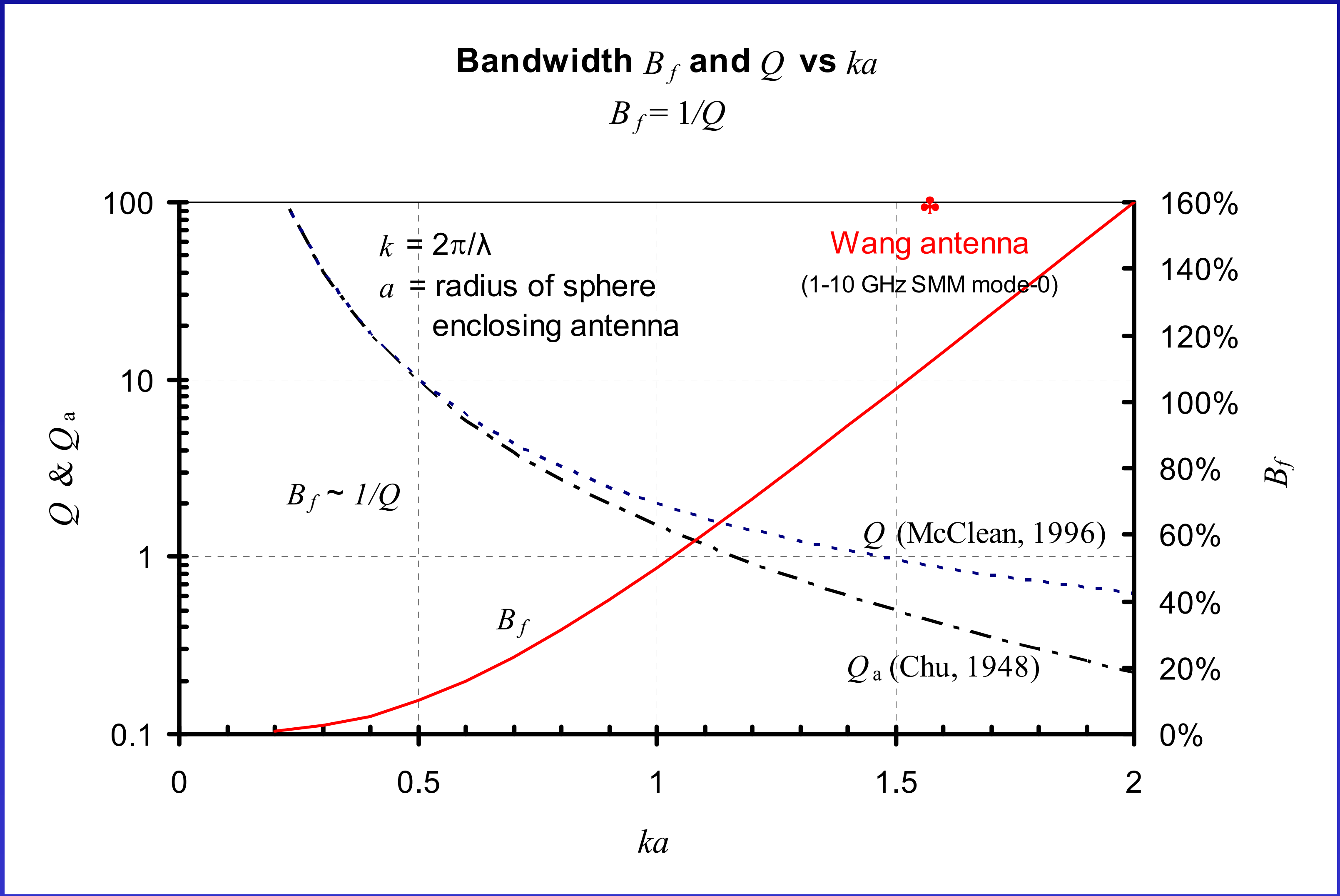
Bandwidth of This Antenna Exceeds the Limitation Imposed by Classical Theory?!

For the 1-10 GHz WEO model

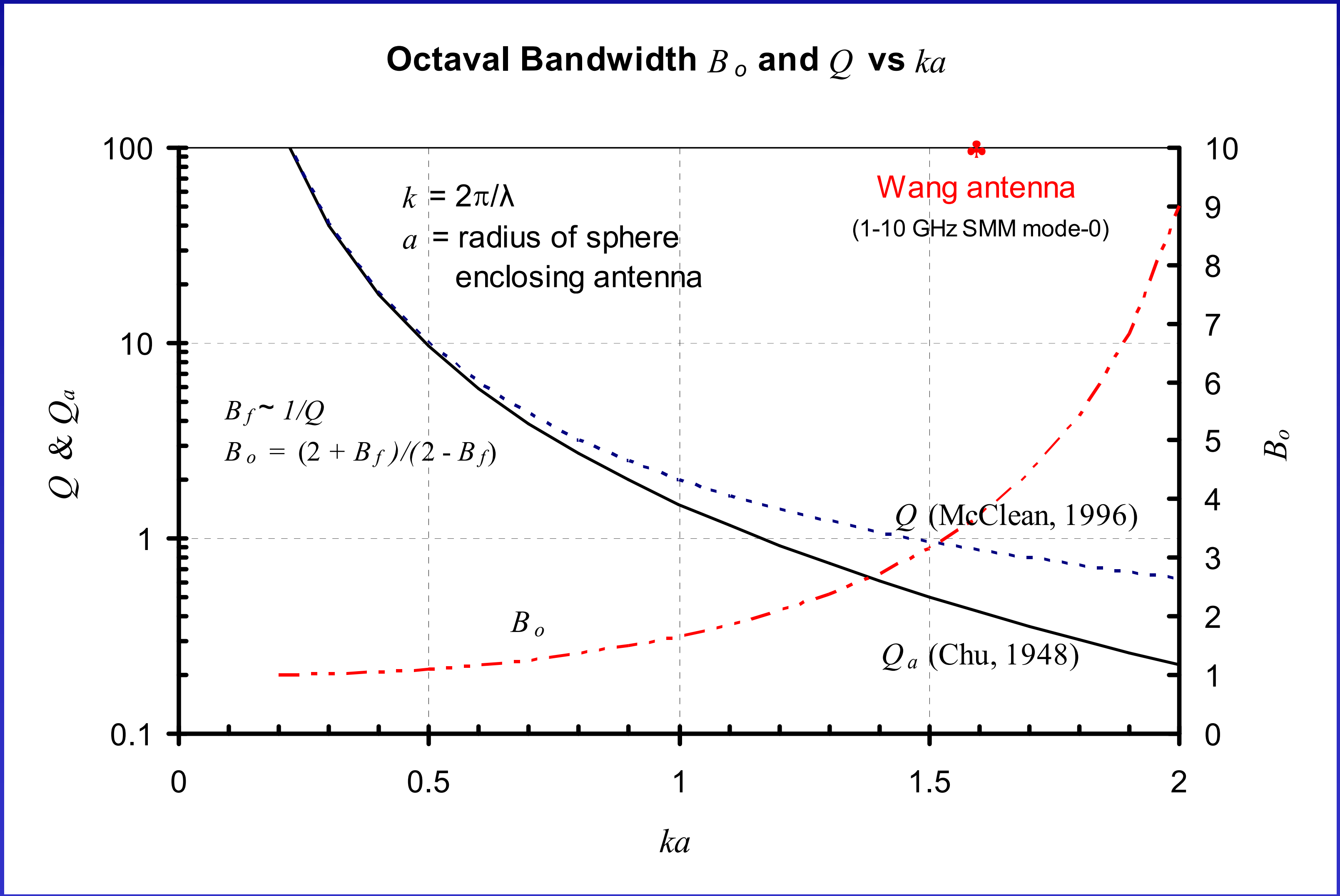
- Theoretical limitation
  - $ka = 2\pi \times 3/11.3 = 1.597$ at 1 GHz
  - $Q_{exact} = 0.869$
  - $B_f = 1/\, Q_{exact} = 115\%$
  - $B_O = (2 + B_f)/(2 - B_f)$

    $= 3.711$ (computed based on Q_{exact})
- Measured bandwidth (1 dBi minimum gain)
  - $B_f = 164\%$
  - $B_O = 10$

Fractional Bandwidth Limitation versus Antenna Size *ka*



Bandwidth of Wang Antenna Is Beyond the Classical Theoretical Physical Limitation!?



Concluding Remarks

- Classical Chu theory on antenna bandwidth limitation is not applicable to broadband antennas.
- Limitation of antenna bandwidth
  - depending on the performance criteria
- The fractional bandwidth, and quality factor Q
  - inadequate for broadband antennas
- For broadband antennas
  - "Octaval Bandwidth" is a more appropriate and even necessary concept/terminology.